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U.S. Army Environmental Center

Compost Compaction Evaluation

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Aberdeen Proving Ground, MD 21010-5401

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MANAGERS DESIGNERS/CONSULTANTS

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The U.S. Army Environmental Center (USAEC) previously conducted a field-scale demonstration of windrow composting of explosives-contaminated soils at the Umatilla Depot Activity (UMDA) in Hermiston, Oregon. These studies were conducted to obtain windrow composting process design information for the remediation of the explosives washout lagoons at UMDA. Following the field demonstration, this compost compaction evaluation was conducted to determine the final disposal volume requirements.

This evaluation was performed by conducting geotechnical testing and evaluation on finished compost from the windrow composting field demonstration. Geotechnical testing included grain size analysis, liquid/plastic limits, natural moisture content, bulk density, and modified Proctor Compaction testing.

The results of the study indicated that if unaerated windrow composting is employed using the operating parameters developed in the field-scale demonstration, 1 cubic yard of contaminated soil (in-place volume) will result in approximately 1.6 cubic yards of finished compost in the final compacted backfill. Under the current cleanup scenario at UMDA, approximately 3,900 cubic yards of explosives-contaminated soil will be composted which will result in approximately 6,200 cubic yards of backfill material.

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COMPOST COMPACTION EVALUATION

Prepared for:

U.S. Army Environmental Center
Contract No. DACA31-9-D-0079
Report No. ENAEC-TS-CR-93110

October 1993

Prepared by:

Roy F. Weston, Inc.
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INTRODUCTION

The U.S. Army Environmental Center (USAEC) recently completed a demonstration of windrow composting of explosives-contaminated soils at Umatilla Depot Activity (UMDA) in Hermiston, Oregon. This demonstration represented the second phase of field studies conducted at UMDA, and was part of an ongoing effort to develop a composting system which can provide an economical and effective alternative to incineration for the treatment of explosives-contaminated soils and sediments.

Most of the research, engineering, and technology development associated with these composting studies have addressed chemical and microbiological aspects of the composting process, including contaminant removal efficiencies, optimal operating conditions, and amendment selection. Less effort has been devoted to developing materials handling strategies. Efficient storage, handling, and disposal of compost, soil, and amendments have been minor concerns in the field-scale demonstrations, but they will become increasingly complex and warrant considerable attention in full-scale operations.

Of the materials handling concerns, one of the most critical is the volume of finished compost that will require disposal. A frequently cited disadvantage of composting, particularly for hazardous wastes, is that the final product has a greater volume than the original soil or sediment that was excavated for treatment. This is due to the addition of amendments and bulking agents to these soils during the formation of the compost mixture. As a result, if the finished compost is backfilled in the excavation from which the original contaminated soil was removed, there will be an excess volume that must be mounded over the excavation site and capped to promote proper drainage. If space is limited or mounding is not an option for other reasons, this excess compost may require offsite disposal.

In general, estimates of final compost volumes have been based upon rough assumptions, and in some cases, these volumes have been greatly overestimated. The purpose of this report is to present a preliminary estimation of the final compacted volume of treated compost to be backfilled at UMDA following full-scale remediation of the washout lagoons

soils. The calculations have been based on a combination of field observations, laboratory analyses, and theoretical calculations. Ultimately, the final compost volume is presented in terms of the initial in-place volume of explosives-contaminated soils to be excavated from the washout lagoons site at UMDA.

GENERAL PROCESS DESCRIPTION

Figure 1-1 presents a flow diagram of the changes in material volume throughout the composting process. The initial in-place ("*in-situ*") contaminated soil volume to be excavated (V_1), represents the primary independent variable in the calculation. This in-place soil volume is determined through a combination of soil sampling to delineate the extent of the contamination, and risk-based clean-up criteria to specify which soils must be excavated and treated. Once the in-place volume of soil to be excavated has been determined, all other volumes can be estimated in terms of this initial volume.

The excavation of the soils results in a stockpiled volume (V_2) of unconfined soil which is slightly greater than the original in-place volume due to a natural bulking of the material upon removal. These stockpiled soils are then incorporated into the initial compost mixture, resulting in an increased material volume (V_3). The extent of this volume increase is dependent on the soils loading rate specified by the compost recipe. Clearly, the higher the percentage of soil in the compost, the lower the overall volume of compost which will be created. Field studies have shown, however, that there is a limit to the soil percentage that can be successfully composted. As a result, soil loading rates of 10-40 percent by volume represents the standard range for composting of explosives-contaminated soils (1,2,3). This equates to an initial mixed compost volume (V_3) from 250% to 1000% of the unconfined soil volume (V_2).

Once the compost mixture has been blended and formed into windrows, the volume of material will gradually decrease over time for a variety of reasons. Part of this volume decrease is due solely to the pulverization of the compost material by the windrow turner which results in smaller particle size and less pore space in the compost pile. In addition,

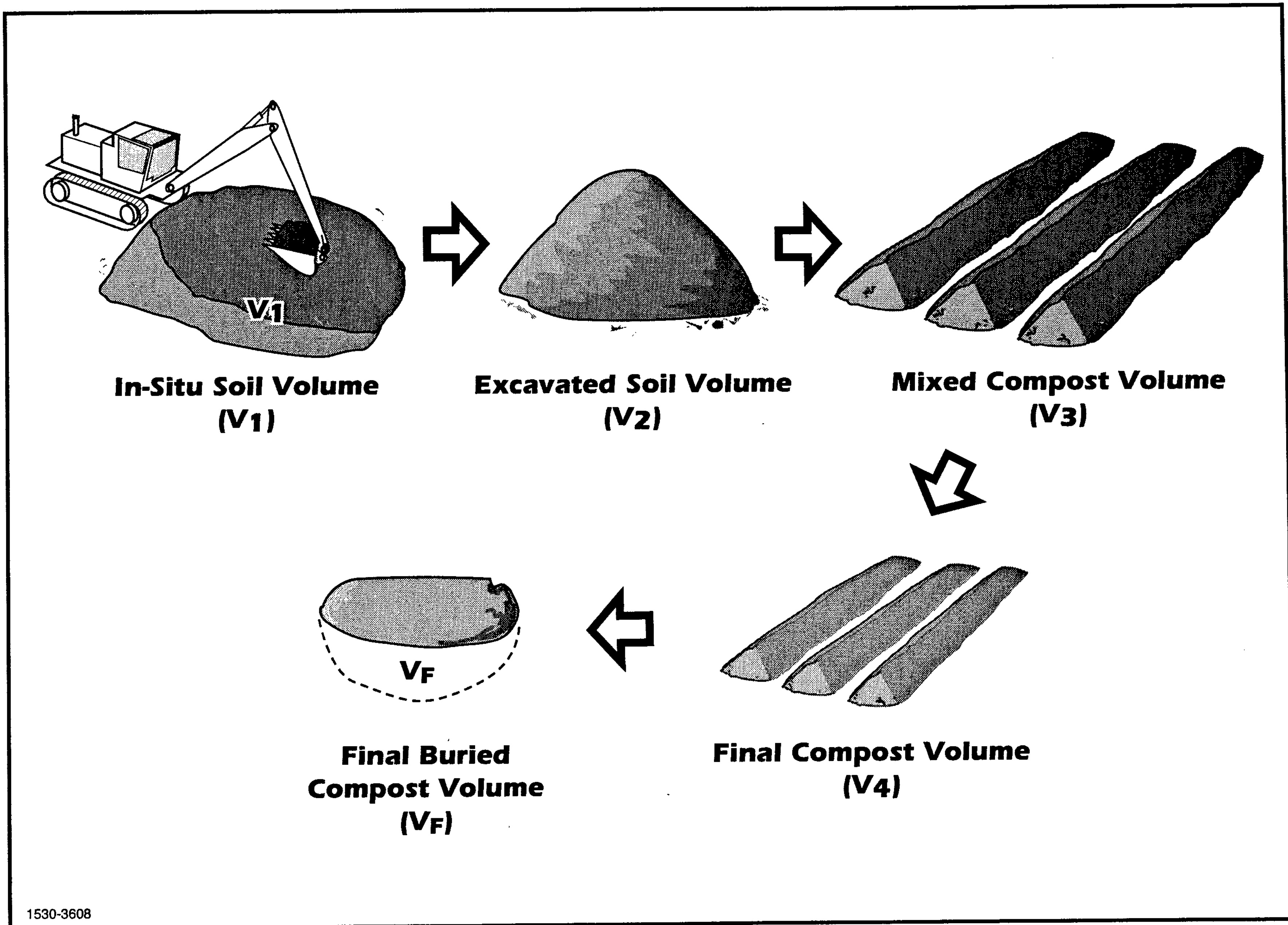

FIGURE 1-1 COMPOSTING PROCESS FLOW DIAGRAM

a substantial portion of the organic matter will be respired by microorganisms to carbon dioxide and water which will then escape from the pile into the air. Based on the observations made during the field demonstration at UMDA, it appears that the decrease in volume (V_4) of the windrow by the end of the composting period will be 30 to 40% of the initial compost volume.

Finally, this finished compost material must be backfilled into the original excavation. Provided that the material is carefully replaced and compacted in thin lifts, a substantial reduction in the volume of the compost may be attainable. The extent of the compaction and volume reduction can be estimated by standard laboratory compaction tests conducted on representative samples of compost. Knowing this final compacted compost volume (V_F) in terms of the original in-place soil volume (V_1) is necessary to determine whether substantial excess compost will be created by the composting process, and whether backfilling the excavation and mounding this excess compost will be feasible for the site in question.

DETAILED ANALYSIS FOR WASHOUT LAGOONS

The procedure presented above for determining final compost volumes is a generic procedure which can be used for any composting site. Many of the calculations required to obtain actual volumes, however, are based on compost-specific characteristics such as amendment selection, soil loading rates, type of composting operation (windrow vs. static pile), and duration of each composting cycle. For the soils at UMDA, conventional windrow composting (as opposed to aerated windrow or aerated static pile composting) has been shown to be most effective at reducing the explosives levels in the soils (4). As a result, it is anticipated that a conventional windrow composting system will be employed for the full-scale remediation of the explosives washout lagoons soils at UMDA. The data and observations obtained from the field demonstration have been used to develop a quantitative relationship between the in-place soil volumes determined during the Remedial Investigation of the site, and the final backfilled compost volumes which will be created as a result of the full-scale composting project.

During the Remedial Investigation conducted for the explosives washout lagoons at UMDA, the volume of soil for excavation was estimated based on four different clean-up scenarios. Under the most stringent scenario, nearly 27000 cubic yards of soil would need to be removed, while under the least restrictive clean-up scenario, only 2100 cubic yards would be excavated (5). It is anticipated that the actual full-scale remediation will require the excavation of a volume of soil somewhere between these two extremes. As a result, the calculations that follow assume an initial in-place soil volume (V_1), independent of the selected clean-up scenario.

During the excavation of the in-place soils (V_1), there will be a natural bulking of the soil which will result in an unconfined soil volume (V_2) slightly greater than the in-place volume. While the Feasibility Study report (5) assumed a bulking factor of 0.2, experience has shown that a more conservative value of 0.25 may be more appropriate. As a result, the volume of unconfined soils resulting from the excavation of the washout lagoons can be expressed as:

$$V_2 = 1.25 * V_1$$

In the next step, the unconfined soils will be blended with the amendments and bulking agents to create the initial compost mixture. Based on the results obtained for the field-scale windrow composting demonstration, it appears that a soil loading rate as high as 30% by volume can be successfully implemented for the composting of the washout lagoon soils. This 30% loading rate means that the remaining 70% by volume of the initial compost mixture will be composed of the carefully selected amendments and bulking agents. This equates to a 333% increase in total material volume from the unconfined stockpiled soils (V_2) to the initial mixed compost (V_3). In terms of the original in-place soil volume, the initial mixed compost volume can be expressed as:

$$V_3 = V_1 * 1.25 * 3.33 = \mathbf{4.16 * V_1}$$

The above expression indicates that the initial compost mixture volume will be about four times as great as the initial in-place soils prior to excavation.

Once mixed, the compost will undergo a gradual volume reduction due to a combination of factors. First, the machinery used to turn the windrows has been shown to pulverize the compost and reduce the particle size of much of the material. This results in less pore space and a more tightly packed material by the end of composting cycle than existed at the beginning. In addition, a significant portion of the organic matter is respired by microorganisms during the cycle, which results in the conversion of solids to carbon dioxide and water, which are subsequently released from the pile into the air.

Based upon observations and rough measurements taken during the field-scale demonstration at UMDA (see Appendix A), it appears that by the end of a typical 40-day conventional windrow composting cycle, the compost will undergo a 30% to 40% loss in volume (i.e 60% to 70% remaining). In terms of the initial in-place soil volume, therefore, the final compost volume (V_4) is given by:

$$V_4 = (0.6 \text{ to } 0.7) * V_3 = \mathbf{(2.5 \text{ to } 2.9) * V_1}$$

This indicates that at the end of composting, there will be a volume of material left for disposal that is about two and one-half to three times the original in-place volume of soil excavated.

To determine the further reduction in volume of this material due to compaction when it is backfilled into the original excavation, a set of samples were taken from both the aerated (CWR7) and unaerated (CWR8) contaminated windrow composts remaining from the field demonstration. These samples were taken from composts that had been stored in 55-gallon drums following completion of the field studies, however, this storage should not have affected the results of the laboratory analyses. These samples were shipped to WESTON's Environmental Technology Laboratory where they were analyzed for grain-size, plasticity, natural moisture content, and specific gravity. In addition, a Modified Proctor compaction

test was performed for each sample to determine the moisture-density relationship for the finished compost materials. The results, (presented in Appendix B) indicated that samples taken from the same windrows had similar moisture-density relationships, however, the aerated windrow samples had a maximum dry density of 92 pounds per cubic foot (pcf) at an optimal moisture content of about 20% (dry basis), while the unaerated windrows demonstrated a maximum dry density of 84 pcf at an optimal moisture of 27%. This difference between the two windrows may be attributed to a difference in compost composition between the two windrows resulting from the aeration variable. Nonetheless, the samples from both windrows classify as silty sand (based on the Unified Soil Classification System), were non-plastic, exhibited a natural moisture content of approximately 40% (dry basis), and were composed of solids with a specific gravity of about 2.6.

To calculate the reduction in the compost volume due to backfilling that will occur in the full-scale operation, it was assumed that a conventional windrow will be used, therefore, compaction study results for the unaerated windrow (CWR8) were used in the calculations. It was also assumed that up to 95% of the maximum dry density determined in the laboratory can actually be obtained using controlled, thin-lift backfill placement and compaction techniques. Using the conservation of mass law, the volume reduction calculation simplifies to determining the number of unit volumes of finished compost which will provide the weight of solids that will be contained in a unit volume of the backfilled compost if it is compacted to 95% of the maximum dry density determined through the laboratory analysis of the compost samples.

The first step in these calculations is to carefully characterize the finished compost material in terms of the total volume and proportions of solids, water, and pore space. These are given by the following basic soil mechanics equation:

$$V_t = V_s + V_a + V_w$$

where,

V_t = total volume of finished compost (consider 1 ft.^{3})
V_s = volume of solids in the compost

V_a = volume of air space in the compost
V_w = volume of water in the compost

The bulk density (wet basis) of the final compost in the conventional windrow was determined previously during biochemical and microbiological studies (6) and was 63 pcf. Knowing this, and using the known moisture content (dry basis) and solids specific gravity of 40% and 2.6 respectively, the volume percentages for each of the compost constituents (solid, water, and air) can be calculated as follows (see Appendix C for definition of terms):

$$V_{si} = \left[\frac{\gamma wet}{(1+w)}\right] \div (G_s x 62.4)$$

$$= \left[\frac{63}{1+0.40}\right] \div (2.6X62.4)$$

$$\mathbf{V_{si} = 0.28ft^3 (28\%)}$$

$$V_{wi} = w\left[\frac{\gamma wet}{(1+w)}\right] \div 62.4$$

$$= 0.40\left(\frac{63}{1+0.40}\right) \div 62.4$$

$$\mathbf{V_{wi} = 0.29ft.^3 (29\%)}$$

and therefore,

$$V_{ai} = V_{ti} - (V_s + V_w)$$

$$= 1 - (0.28 + 0.29)$$

$$\mathbf{V_{ai} = 0.43ft^3 (43\%)}$$

Next, it was assumed that the compost can be compacted to 95% of its maximum dry density, which is a typical requirement for structural fill that can be attained with standard

Next, it was assumed that the compost can be compacted to 95% of its maximum dry density, which is a typical requirement for structural fill that can be attained with standard backfill equipment and verified with field instruments. From the moisture-density relationship presented for the conventional windrow samples (Appendix C) at 95% compaction, the moisture content will be approximately 33% (dry basis) and the dry density will be 80 pcf. For simplicity, it can be assumed that the volume and weight of dry solids in the compost material will not change during backfilling. As a result, if one calculates the weight of dry solids in a unit volume of finished compost, and compares the result with the known backfilled dry density of 80 pcf, then the number of finished compost volumes necessary to create a single backfilled volume can be calculated, and this can ultimately be expressed in terms of the initial in-place soil volume. The previous calculations showed that each cubic foot of finished compost is 28% solids by volume. Knowing that the specific gravity of the solids is 2.6, then the weight of solids in each cubic foot of finished compost is given by:

$$W_{si} = 0.28 \text{ ft.}^3 * 2.6 * 62.4 \text{ pcf} \approx 45 \text{ pounds}$$

This indicates that for every unit volume of backfill, 80/45 or 1.78 unit volumes of finished compost will be required. In terms of the original volume of in-place soils, this is:

$$V_F = \frac{V_4}{1.78} = \frac{(2.5 \text{ to } 2.9) \text{ x } V_1}{1.78}$$

$$V_F = (1.40 \text{ to } 1.63) \text{ x } V_1$$

The above results indicates that for every cubic yard of contaminated soil that is excavated, there will be an extra 0.40 to 0.63 cubic yards of material volume in the backfill.

The one last calculation which is necessary is a moisture balance on the material. From the volume percentages calculated previously, the volume of water in 1.78 cubic feet of finished compost is given by:

$$V_w = 1.78 \times 0.29 = 0.52 \text{ ft}^3$$

Following compaction, the volume of the compost is reduced to 1 cubic foot and the volume of moisture in this cubic foot is given by:

$$V_{wt} = (0.33 \times 80) \div 62.4 = 0.42 \text{ ft}^3$$

This indicates that 0.10 cubic feet of water will be squeezed from the compost for every 1.78 cubic feet that are backfilled. Much of this water will evaporate from the surface of the backfill. Any water that drains from the backfill will be collected and either recycled into the composting operation or placed within the evaporation ponds at UMDA.

IMPLICATIONS OF CALCULATIONS

The results of the calculations indicate that for every cubic yard of in-place soils which are excavated, a backfilled volume of up to 1.6 cubic yards will be created. Under the current proposed remediation at the washout lagoons, 3900 cubic yards of in-place soil would be excavated, which according to these calculations, will result in about 6200 cubic yards of backfilled material. This material will be backfilled into the original excavation (3900 cubic yards), and also into the existing lagoons which have a volume of about 1200 cubic yards. This leaves a total of 1100 cubic yards which will need to be mounded above the ground surface. If spread evenly over the surface of the site, this mound would be only 1.7 feet deep. Of course to promote runoff, the excess material may have to be mounded higher in the center and less around the perimeter.

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1. WESTON (Roy F. Weston, Inc.). 1988. Field Demonstration of Explosives-Contaminated Sediments at the Louisiana Army Ammunition Plant (LAAP), Final Report, prepared for USAEC, Report No. AMXTH-IR-TE-88242.

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5. CH2M Hill/Morrison Knudsen. 1992. Feasibility Study for the Explosives Washout Lagoons (Site 4) Soils Operable Unit, Umatilla Depot Activity (UMDA), Hermiston, Oregon, Final Report, prepared for USAEC, Report No. CETHA-BC-CR-92017.

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APPENDIX A

ESTIMATION OF ΔV DURING COMPOST CYCLE

APPENDIX A

ESTIMATION OF ΔV DURING COMPOST CYCLE

As part of the calculation of final compost volume, it is necessary to estimate the total volume reduction which will occur due to both pulverization of the compost by the windrow turner and biological degradation of the organic matter. This volume reduction is very compost-specific and depends upon such factors as soil loading rates, types and amounts of specific amendments and bulking agents, type of composting system employed, and the duration of the composting cycle. As a result, it was determined that the most accurate way to assess this volume reduction would be to base it on observations of the windrow dimensions before and after composting.

The estimation of volume reduction was conducted for two different windrows (one uncontaminated and one contaminated) both of which contained an initial compost mixture composed of 30% soil by volume. For the uncontaminated windrow, the recipe called for an initial compost volume of 31 cubic yards of material. The approximate windrow dimensions after the 40-day composting cycle were as follows:

- base width = 10.5 ft
- top width = 1 ft
- height = 2.75 ft
- length = 28 ft

Calculating the volume of the compost based upon these dimensions gives a final compost volume of 16.4 yd^3. This is equivalent to a 47% decrease in volume. For the contaminated windrow, the initial recipe again called for 31 yd^3 of material. However, an additional 5 yd^3 of amendment materials were later added as part of a supplementation study. The final dimensions of this pile at the end of the composting cycle were:

- base width = 10 ft
- top width = 1 ft
- height = 4 ft
- length = 28 ft

This is approximately equal to 25.2 yd^3 of compost which is equivalent to a 30% reduction in volume.

Because the above two calculations yielded varied results, a third calculation was performed to try to theoretically predict the volume reduction to be expected. This calculation assumed that the observed 20% increase in bulk density of the compost over the 40-day cycle was due to the mineralization of the lighter organic portion of the compost, resulting in a higher proportion of the higher density soil in the mixture. This calculation predicted a 38% reduction in volume.

Based on these three calculations, it was estimated that a 30% to 40% volume reduction would be an accurate, yet conservative estimate of the material loss in a windrow composting operation based on a recipe similar to that used in the field demonstration at UMDA.

APPENDIX B

GEOTECHNICAL LABORATORY RESULTS

Inter-Office Memorandum

WESTON MANAGERS DESIGNERS/CONSULTANTS

TO: Bill Lowe

cc: Jamie Coffman

FROM: Russell Frye

DATE: 26 May 1993

PROJECT: Umatilla

W.O. NO.: 02281-012-001-0006

SUBJECT: **Geotechnical Testing Results**

ACTION:

Geotechnical testing results for the Umatilla project are attached. Four (4) soil samples, job number 9304X014 were submitted to WESTON's Environmental Technology Laboratory (ETL) on 30 April 1993 for geotechnical testing.

The geotechnical tests requested are presented in the attached custody transfer/work request.

The geotechnical tests performed including reference method and test number are presented in Table 1.

If you require additional information or have any questions, please call me at (215) 524-6173.

Table 1
Geotechnical Tests Performed, Reference Methods and Test Numbers

Test Parameter	Method[1]	Test Numbers
Grain Size by Sieve and Hydrometer	D 421/422	4
Liquid and Plastic Limits	D 4318	4
Natural Moisture Content	D 2216	3
Bulk Density (Undisturbed)	D 2937	3
Modified Proctor Compaction Test	D 1557	4

[1] All analytical methods derived from the Annual Book of ASTM Standards, Section 4, Volume 4.08, Soil and Rock; Building Stones; Geotextiles, American Society of Testing Materials, Philadelphia, PA, 1991 unless noted otherwise.

Custody Transfer Record/Lab Work Request

WESTON

WESTON Analytics Use Only
9304X014

Client UMATILLA
Work Order 02281-012-001-0006-00
Date Rec'd. 4/30/93 Date Due 5/28/93
RFW Contact Russell Frye 6173
Client Contact/Phone Bill Lowe 3762

Refrigerator#									
#/Type Container									
Volume									
Preservative									
ANALYSES REQUESTED →			BDS*	NMC	LPL**	GSC	CTM		

WA Use Only Lab ID	Client ID/Description	Matrix	Date Collected	BDS* (1)	NMC	LPL**	GSC	CTM
001	CWR-7A	S	4/20/93	X	X	X	X	X
002	CWR-7B	S	↓	X	X	X	X	X
003	CWR-8A	S	↓	X	X	X	X	X
004	CWR-8B	S	↓	~~X~~	~~X~~	X	X	X

Cancelled see note (1) [initials] 5/24/93

Matrix:
S - Soil, SE - Sediment, SO - Solid
W - Water, O - Oil, A - Air, WI - Wipe
DS - Drum Solids, DL - Drum Liquids, F - Fish, L - EP/TCLP Leachate
X - Other

WORK REQUEST RECEIVED 4/30/93

Special Instructions: * BDS on undisturbed tube specimens
** may not be cohesive ?
(1) no undisturbed sample received for sample 004
therefore NMC & BDS cancelled

Item/Reason	Relinquished by	Received by	Date	Time	Item/Reason	Relinquished by	Received by	Date	Time
ship to	Fed X	[signature]	4/21/93	1000					

WESTON Analytics Use Only

Samples Were:
1 Shipped or Hand-Delivered
NOTES:

2 Ambient or Chilled
NOTES:

3 Received Broken/Leaking (Improperly Sealed)
Y N
NOTES:

4 Properly Preserved
Y N
NOTES:

5 Received Within Holding Times
Y N
NOTES:

COC Tape Was:
1 Present on Outer Package Y N
2 Unbroken on Outer Package Y N
3 Present on Sample Y N
4 Unbroken on Sample Y N
NOTES:

COC Record Was:
1 Present Upon Receipt of Samples Y N

Discrepancies Between Sample Labels and COC Record? Y N
NOTES:

RFW 21-21-001/A-12/88

7-115

WESTON ENVIRONMENTAL TECHNOLOGY LABORATORY

GEOTECHNICAL TESTING DATA AND RESULTS

PROJECT	UMATILLA	PROJECT SAMPLE I.D.	CWR-7A	PROJECT ANALYST	SPM
JOB NUMBER	9304X014	ETL SAMPLE NUMBER	001	QA/QC ANALYST	RWF
W. O. NUMBER	02281-012-001-0006-00	DATE RECEIVED	4/21/93	DATE COMPLETED	05/20/93

PARTICLE SIZE DISTRIBUTION

U. S. Standard Sieve Size	Diameter mm	% Finer
3"	75.00	100.0
1 1/2"	37.50	100.0
3/4"	19.00	99.8
3/8"	9.500	98.8
#4	4.750	96.1
#10	2.000	94.6
#20	0.850	90.0
#50	0.300	64.1
#100	0.150	36.0
#200	0.075	23.8
HYDROMETER	0.0445	22.3
	0.0334	16.5
	0.0241	14.4
	0.0171	13.7
	0.0127	12.3
	0.0091	10.8
	0.0065	10.1
	0.0046	8.7
	0.0033	7.3
	0.0023	7.3
	0.0014	5.8
	0.0010	5.1

EFFECTIVE SIZES

% Finer	Diameter mm
60	0.278
30	0.113
10	NA
Uniformity Coefficient	Gradation Coefficient
NA	NA

NATURAL MOISTURE CONTENT, % dry basis

39.9

SAMPLE DESCRIPTION

brown SAND with 4% gravel and 24% silt

Unified Soil Classification System (USCS) Group Symbol

SM

INDEX PROPERTIES
% moisture dry basis

Liquid Limit	Plastic Limit	Plasticity Index
non-plastic, non-cohesive		

BULK DENSITY

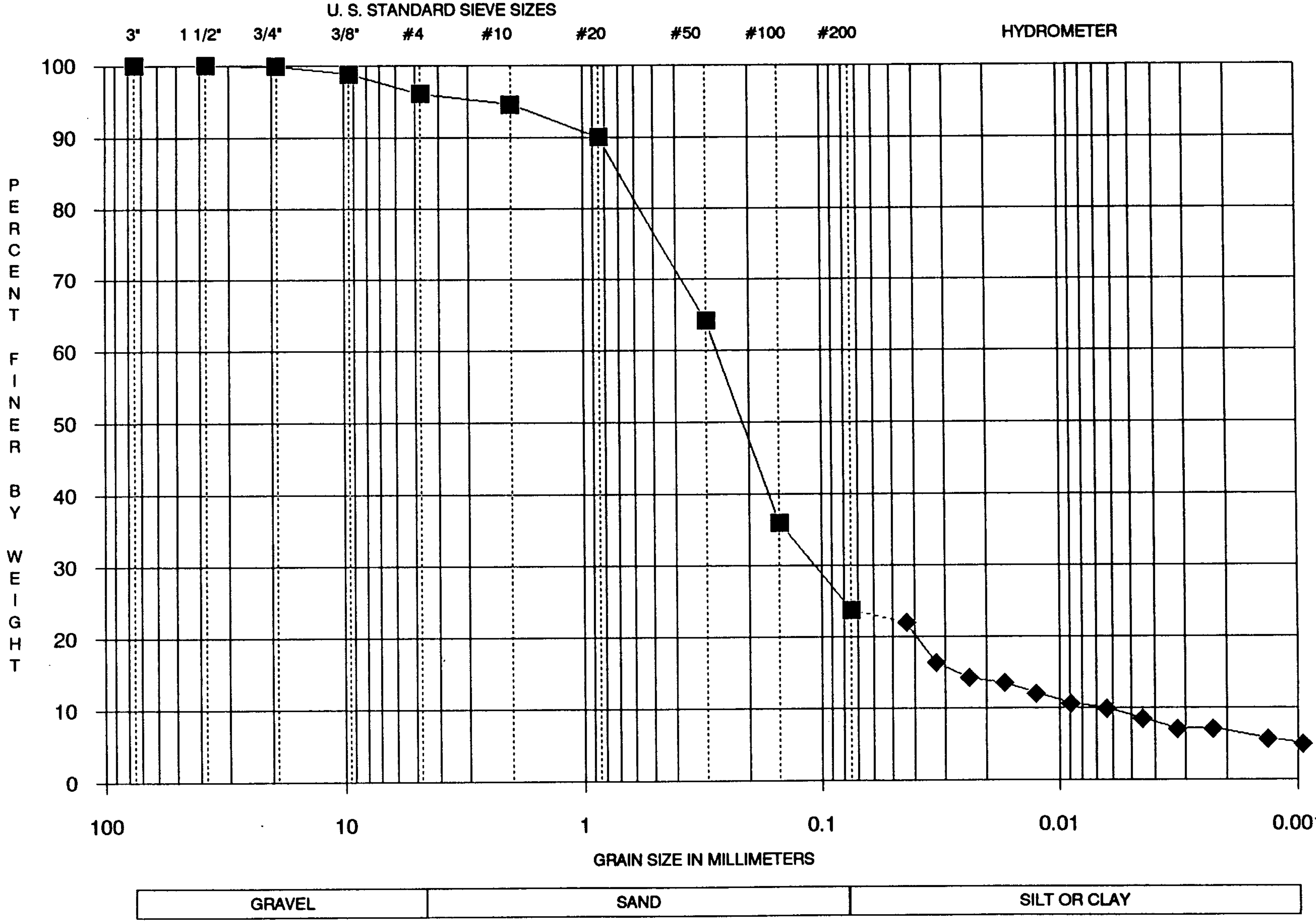
Wet Density g/cc	Unit Weight, pcf	
	Wet	Dry
1.29	80.6	57.6

NOTES

NA=NOT APPLICABLE

WESTON ENVIRONMENTAL TECHNOLOGY LABORATORY

PARTICLE-SIZE DISTRIBUTION CURVE FOR UMATILLA PROJECT SAMPLE CWR-7A, ETL SAMPLE # 9304X014-001



WESTON ENVIRONMENTAL TECHNOLOGY LABORATORY

GEOTECHNICAL TESTING DATA AND RESULTS

PROJECT	UMATILLA	PROJECT SAMPLE I.D.	CWR-7B	PROJECT ANALYST	SPM
JOB NUMBER	9304X014	ETL SAMPLE NUMBER	002	QA/QC ANALYST	RWF
W. O. NUMBER	02281-012-001-0006-00	DATE RECEIVED	4/21/93	DATE COMPLETED	05/20/93

PARTICLE SIZE DISTRIBUTION

U. S. Standard Sieve Size	Diameter mm	% Finer
3"	75.00	100.0
1 1/2"	37.50	100.0
3/4"	19.00	100.0
3/8"	9.500	98.6
#4	4.750	95.9
#10	2.000	93.9
#20	0.850	88.9
#50	0.300	58.0
#100	0.150	32.5
#200	0.075	21.6
HYDROMETER	0.0445	23.6
	0.0334	17.6
	0.0241	15.3
	0.0173	13.8
	0.0127	13.0
	0.0091	11.5
	0.0065	10.0
	0.0047	8.5
	0.0033	7.7
	0.0023	7.7
	0.0014	6.2
	0.0010	5.5

EFFECTIVE SIZES

% Finer	Diameter mm
60	0.336
30	0.133
10	NA
Uniformity Coefficient	Gradation Coefficient
NA	NA

NATURAL MOISTURE CONTENT, % dry basis

40.4

SAMPLE DESCRIPTION

brown SAND with 4% gravel and 22% silt

Unified Soil Classification System (USCS) Group Symbol

SM

INDEX PROPERTIES
% moisture dry basis

Liquid Limit	Plastic Limit	Plasticity Index
non-plastic, non-cohesive		

BULK DENSITY

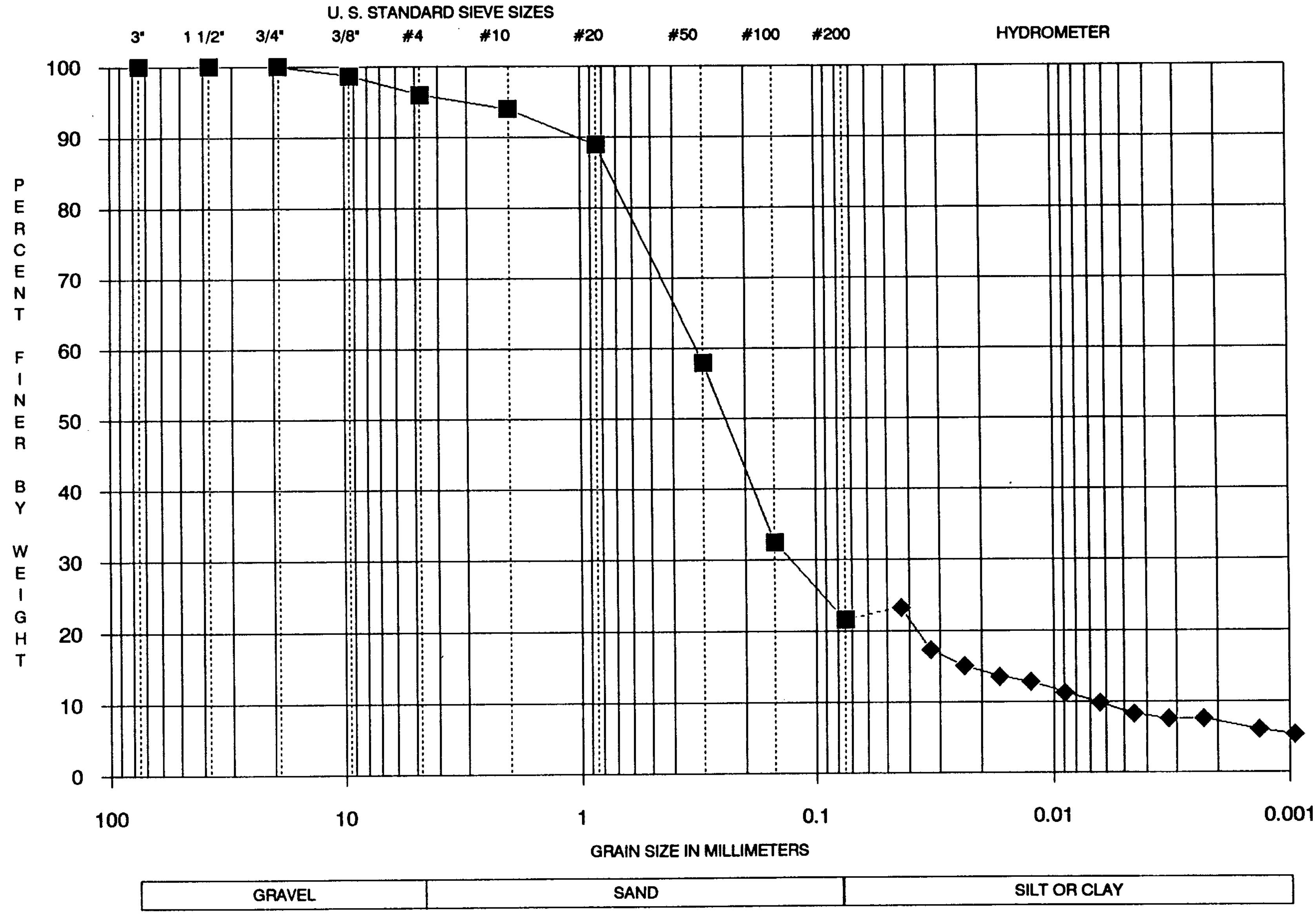
Wet Density g/cc	Unit Weight, pcf	
	Wet	Dry
1.16	72.2	51.4

NOTES

NA=NOT APPLICABLE

WESTON ENVIRONMENTAL TECHNOLOGY LABORATORY

PARTICLE-SIZE DISTRIBUTION CURVE FOR UMATILLA PROJECT SAMPLE CWR-7B, ETL SAMPLE # 9304X014-002



WESTON ENVIRONMENTAL TECHNOLOGY LABORATORY

GEOTECHNICAL TESTING DATA AND RESULTS

PROJECT	UMATILLA	PROJECT SAMPLE I.D.	CWR-8A	PROJECT ANALYST	SPM
JOB NUMBER	9304X014	ETL SAMPLE NUMBER	003	QA/QC ANALYST	RWF
W. O. NUMBER	02281-012-001-0006-00	DATE RECEIVED	4/21/93	DATE COMPLETED	05/20/93

PARTICLE SIZE DISTRIBUTION

U. S. Standard Sieve Size	Diameter mm	% Finer
3"	75.00	100.0
1 1/2"	37.50	100.0
3/4"	19.00	100.0
3/8"	9.500	98.9
#4	4.750	95.9
#10	2.000	94.5
#20	0.850	89.2
#50	0.300	63.0
#100	0.150	35.8
#200	0.075	23.1
HYDROMETER	0.0446	23.5
	0.0339	16.2
	0.0246	13.3
	0.0177	11.1
	0.0130	10.4
	0.0093	9.6
	0.0066	8.9
	0.0047	8.2
	0.0033	7.5
	0.0024	6.0
	0.0014	6.0
	0.0010	5.3

EFFECTIVE SIZES

% Finer	Diameter mm
60	0.284
30	0.116
10	NA
Uniformity Coefficient	Gradation Coefficient
NA	NA

NATURAL MOISTURE CONTENT, % dry basis

40.6

SAMPLE DESCRIPTION

brown SAND with 4% gravel and 23% silt

Unified Soil Classification System (USCS) Group Symbol

SM

INDEX PROPERTIES

% moisture dry basis

Liquid Limit	Plastic Limit	Plasticity Index
non-plastic, non-cohesive		

BULK DENSITY

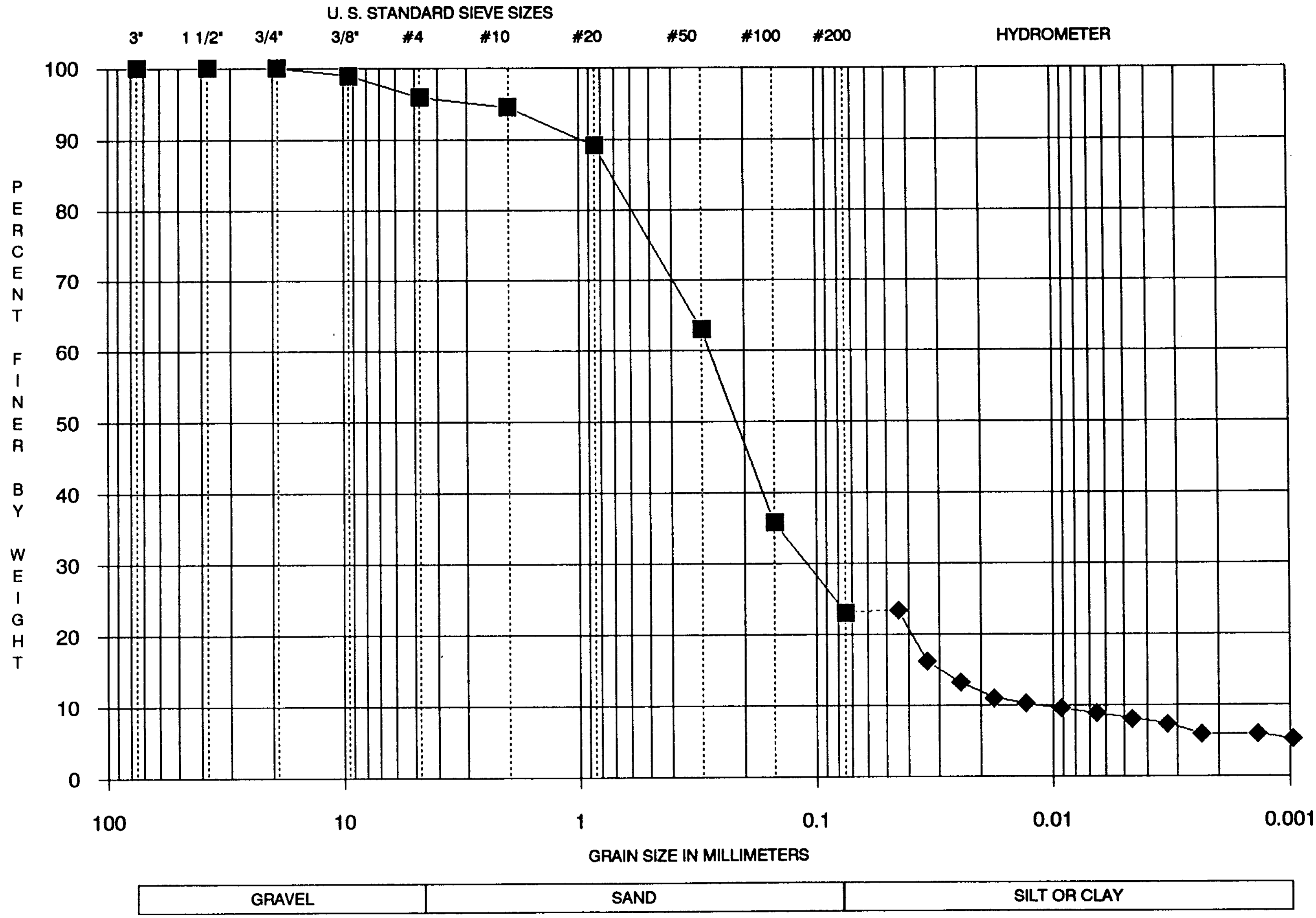
Wet Density g/cc	Unit Weight, pcf	
	Wet	Dry
1.27	79.1	56.3

NOTES

NA=NOT APPLICABLE

WESTON ENVIRONMENTAL TECHNOLOGY LABORATORY

PARTICLE-SIZE DISTRIBUTION CURVE FOR UMATILLA PROJECT SAMPLE CWR-8A, ETL SAMPLE # 9304X014-003



WESTON ENVIRONMENTAL TECHNOLOGY LABORATORY

GEOTECHNICAL TESTING DATA AND RESULTS

PROJECT	UMATILLA	PROJECT SAMPLE I.D.	CWR-8B	PROJECT ANALYST	SPM
JOB NUMBER	9304X014	ETL SAMPLE NUMBER	004	QA/QC ANALYST	RWF
W. O. NUMBER	02281-012-001-0006-00	DATE RECEIVED	4/21/93	DATE COMPLETED	05/20/93

PARTICLE SIZE DISTRIBUTION

U. S. Standard Sieve Size	Diameter mm	% Finer
3"	75.00	100.0
1 1/2"	37.50	100.0
3/4"	19.00	100.0
3/8"	9.500	98.3
#4	4.750	95.2
#10	2.000	93.7
#20	0.850	88.5
#50	0.300	61.0
#100	0.150	37.0
#200	0.075	25.8
HYDROMETER	0.0466	19.2
	0.0350	12.6
	0.0251	11.1
	0.0180	9.7
	0.0132	8.9
	0.0094	8.2
	0.0067	7.5
	0.0047	6.7
	0.0034	6.0
	0.0024	5.3
	0.0014	4.5
	0.0010	3.8

EFFECTIVE SIZES

% Finer	Diameter mm
60	0.294
30	0.103
10	NA
Uniformity Coefficient	Gradation Coefficient
NA	NA

SAMPLE DESCRIPTION

brown SAND with 5% gravel and 26% silt

Unified Soil Classification System (USCS) Group Symbol
SM

INDEX PROPERTIES
% moisture dry basis

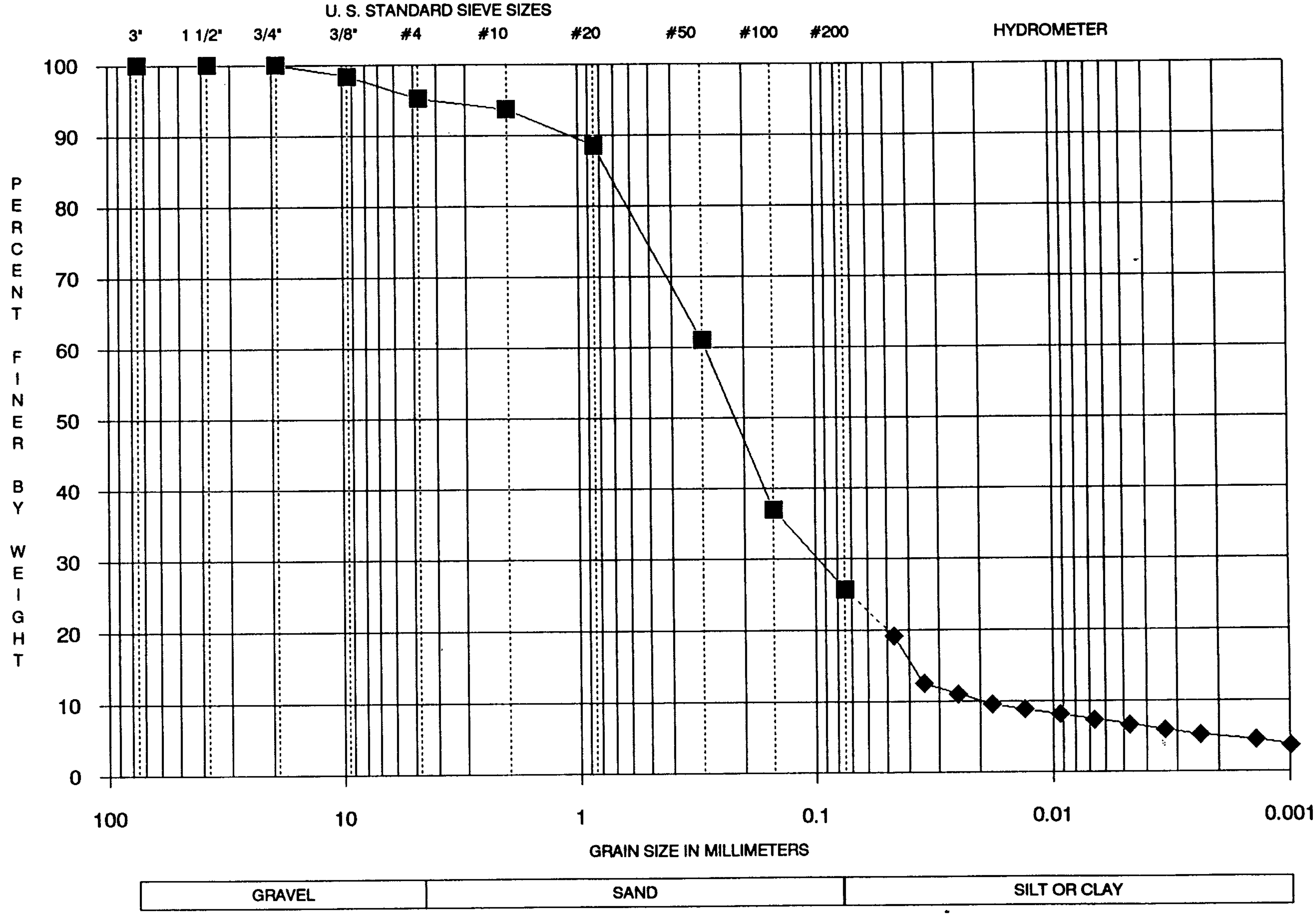
Liquid Limit	Plastic Limit	Plasticity Index
non-plastic, non-cohesive		

NOTES

NA=NOT APPLICABLE

WESTON ENVIRONMENTAL TECHNOLOGY LABORATORY

PARTICLE-SIZE DISTRIBUTION CURVE FOR UMATILLA PROJECT SAMPLE CWR-8B, ETL SAMPLE # 9304X014-004



WESTON ENVIRONMENTAL TECHNOLOGY LABORATORY

SOIL COMPACTION TEST DATA AND RESULTS

PROJECT	UMATILLA	PROJECT SAMPLE ID	CWR-7A
JOB NUMBER	9304X014	ETL SAMPLE NUMBER	001
W. O. NUMBER	02281-012-001-0006-00	TEST DATE	5/11/93

SOIL PROPERTIES					
Soil Description	USCS Class	Natural Moisture %	Plastic Limit %w	Liquid Limit %w	Specific Gravity
brown SAND with 4% gravel and 24% silt	SM	39.9	non- plastic		2.60

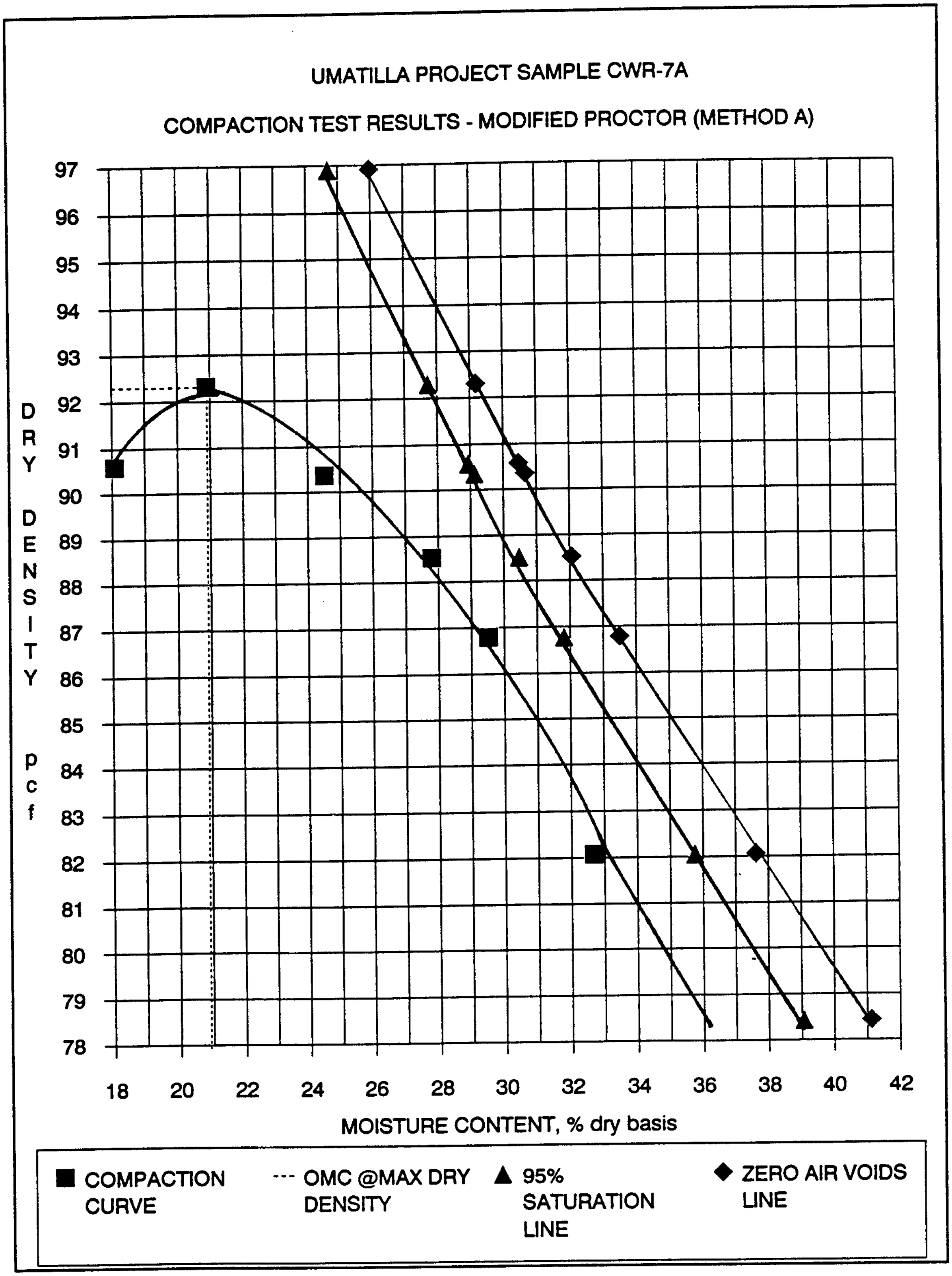
COMPACTION PARAMETERS							
Test Method	Mold Size			Compaction Method			
	Diameter inches	Height inches	Volume cc	Rammer Weight, lb	Rammer Drop, inch	# of Layers	# Blows per Layer
Modified proctor Method A minimum 4 points	3.984	4.570	933.7	10.0	18	5	25

COMPACTION TEST MEASURED RESULTS						
Dry Unit Weight, pcf	90.6	92.3	90.4	88.5	86.8	82.1
Moisture Content, %	18.1	20.9	24.5	27.8	29.5	32.7
Saturated Moisture Content, %	30.5	29.2	30.6	32.1	33.5	37.6
95% Saturated Moisture Content, %	28.9	27.7	29.1	30.5	31.8	35.7

COMPACTION CURVE ANALYSIS/RESULTS						
% of Maximum Dry Density	100	95	90	85		
Dry Density, pcf	92.3	87.7	83.1	78.5		
Moisture Content, %	20.9	28.2	32.4	36.0		
% Points Wet of Optimum	0.0	7.3	11.5	15.1		

NOTES

WESTON ENVIRONMENTAL TECHNOLOGY LABORATORY



WESTON ENVIRONMENTAL TECHNOLOGY LABORATORY

SOIL COMPACTION TEST DATA AND RESULTS

PROJECT	UMATILLA	PROJECT SAMPLE ID	CWR-7B
JOB NUMBER	9304X014	ETL SAMPLE NUMBER	002
W. O. NUMBER	02281-012-001-0006-00	TEST DATE	5/11/93

SOIL PROPERTIES

Soil Description	USCS Class	Natural Moisture %	Plastic Limit %w	Liquid Limit %w	Specific Gravity
brown SAND with 4% gravel and 22% silt	SM	40.4	non- plastic		2.60

COMPACTION PARAMETERS

Test Method	Mold Size			Compaction Method			
				Rammer			
	Diameter inches	Height inches	Volume cc	Weight, lb	Drop, inch	# of Layers	# Blows per Layer
Modified proctor Method A minimum 4 points	3.984	4.570	933.7	10.0	18	5	25

COMPACTION TEST MEASURED RESULTS

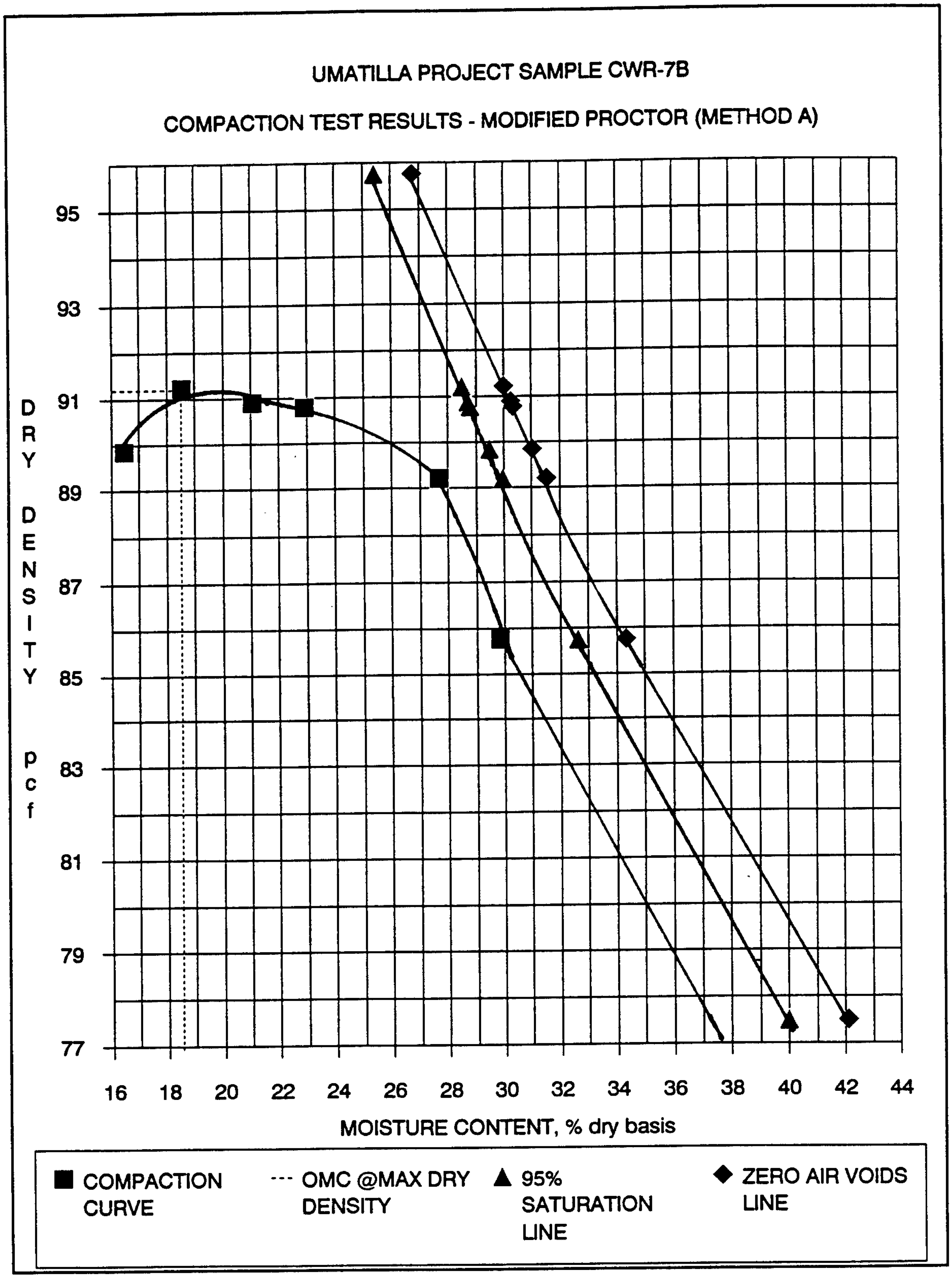
Dry Unit Weight, pcf	89.9	91.2	90.9	90.8	89.2	85.8
Moisture Content, %	16.5	18.5	21.0	22.9	27.7	29.8
Saturated Moisture Content, %	31.0	30.0	30.2	30.3	31.5	34.3
95% Saturated Moisture Content, %	29.5	28.5	28.7	28.8	29.9	32.6

COMPACTION CURVE ANALYSIS/RESULTS

% of Maximum Dry Density	100	95	90	85		
Dry Density, pcf	91.2	86.6	82.1	77.5		
Moisture Content, %	18.5	29.3	33.0	37.3		
% Points Wet of Optimum	0.0	10.8	14.5	18.8		

NOTES

WESTON ENVIRONMENTAL TECHNOLOGY LABORATORY



WESTON ENVIRONMENTAL TECHNOLOGY LABORATORY

SOIL COMPACTION TEST DATA AND RESULTS

PROJECT	UMATILLA	PROJECT SAMPLE ID	CWR-8A
JOB NUMBER	9304X014	ETL SAMPLE NUMBER	003
W. O. NUMBER		TEST DATE	5/11/93

SOIL PROPERTIES

Soil Description	USCS Class	Natural Moisture %	Plastic Limit %w	Liquid Limit %w	Specific Gravity
brown SAND with 4% gravel and 23% silt	SM	40.6	non- plastic		2.57

COMPACTION PARAMETERS

Test Method	Mold Size			Compaction Method			
	Diameter inches	Height inches	Volume cc	Rammer Weight, lb	Rammer Drop, inch	# of Layers	# Blows per Layer
Modified proctor Method A minimum 4 points	3.984	4.570	933.7	10.0	18	5	25

COMPACTION TEST MEASURED RESULTS

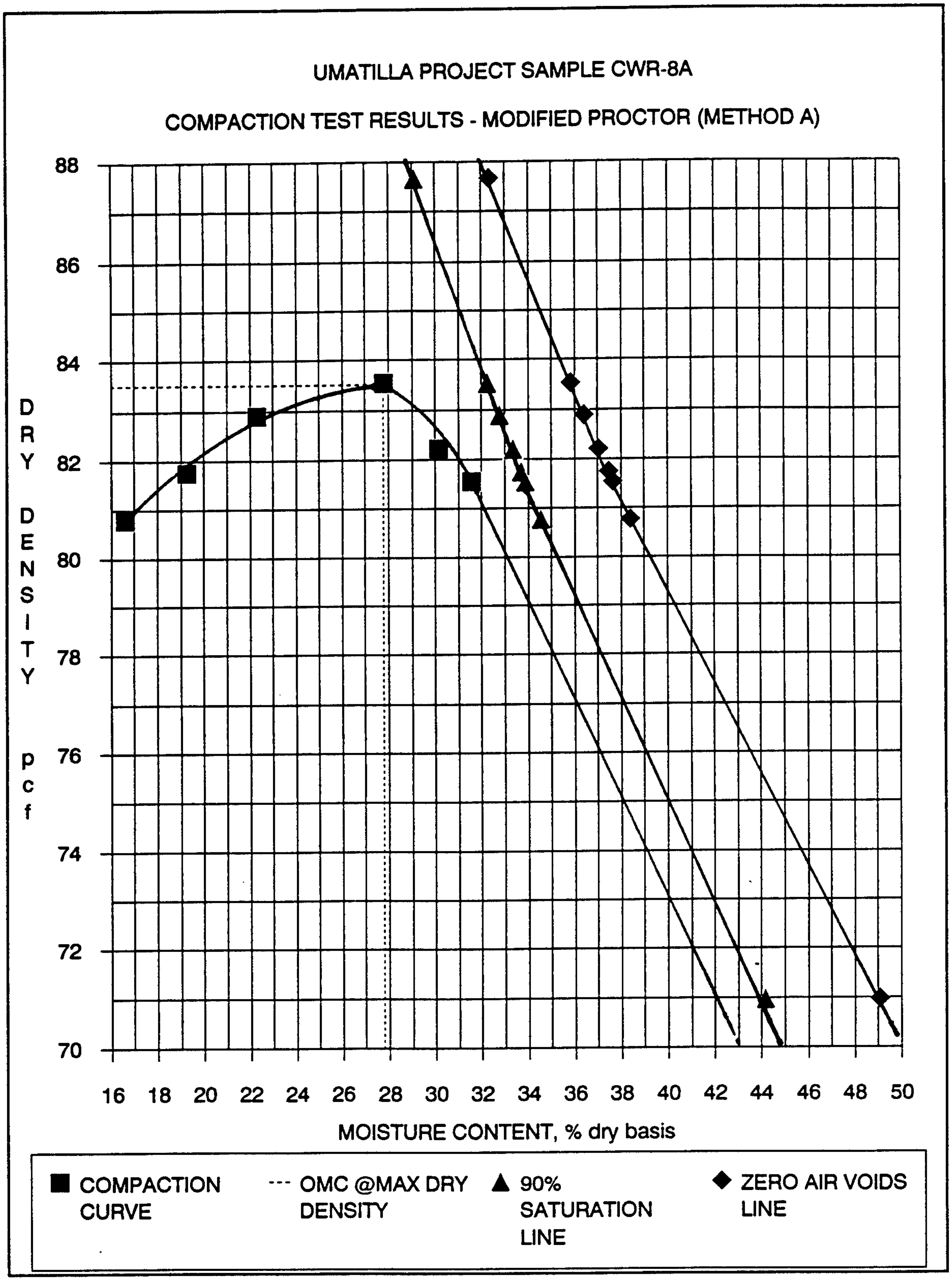
Dry Unit Weight, pcf	80.8	81.8	82.9	83.5	82.2	81.5
Moisture Content, %	16.6	19.2	22.3	27.8	30.2	31.6
Saturated Moisture Content, %	38.4	37.4	36.4	35.8	37.0	37.6
90% Saturated Moisture Content, %	34.5	33.7	32.8	32.2	33.3	33.9

COMPACTION CURVE ANALYSIS/RESULTS

% of Maximum Dry Density	100	95	90	85		
Dry Density, pcf	83.5	79.3	75.2	71.0		
Moisture Content, %	27.8	33.8	37.8	42.0		
% Points Wet of Optimum	0.0	6.0	10.0	14.2		

NOTES

WESTON ENVIRONMENTAL TECHNOLOGY LABORATORY



WESTON ENVIRONMENTAL TECHNOLOGY LABORATORY

SOIL COMPACTION TEST DATA AND RESULTS

PROJECT	UMATILLA	PROJECT SAMPLE ID	CWR-8B
JOB NUMBER	9304X014	ETL SAMPLE NUMBER	004
W. O. NUMBER	02281-012-001-0006-00	TEST DATE	5/11/93

SOIL PROPERTIES					
Soil Description	USCS Class	Natural Moisture %	Plastic Limit %w	Liquid Limit %w	Specific Gravity
brown SAND with 5% gravel and 26% silt	SM		non- plastic		2.57

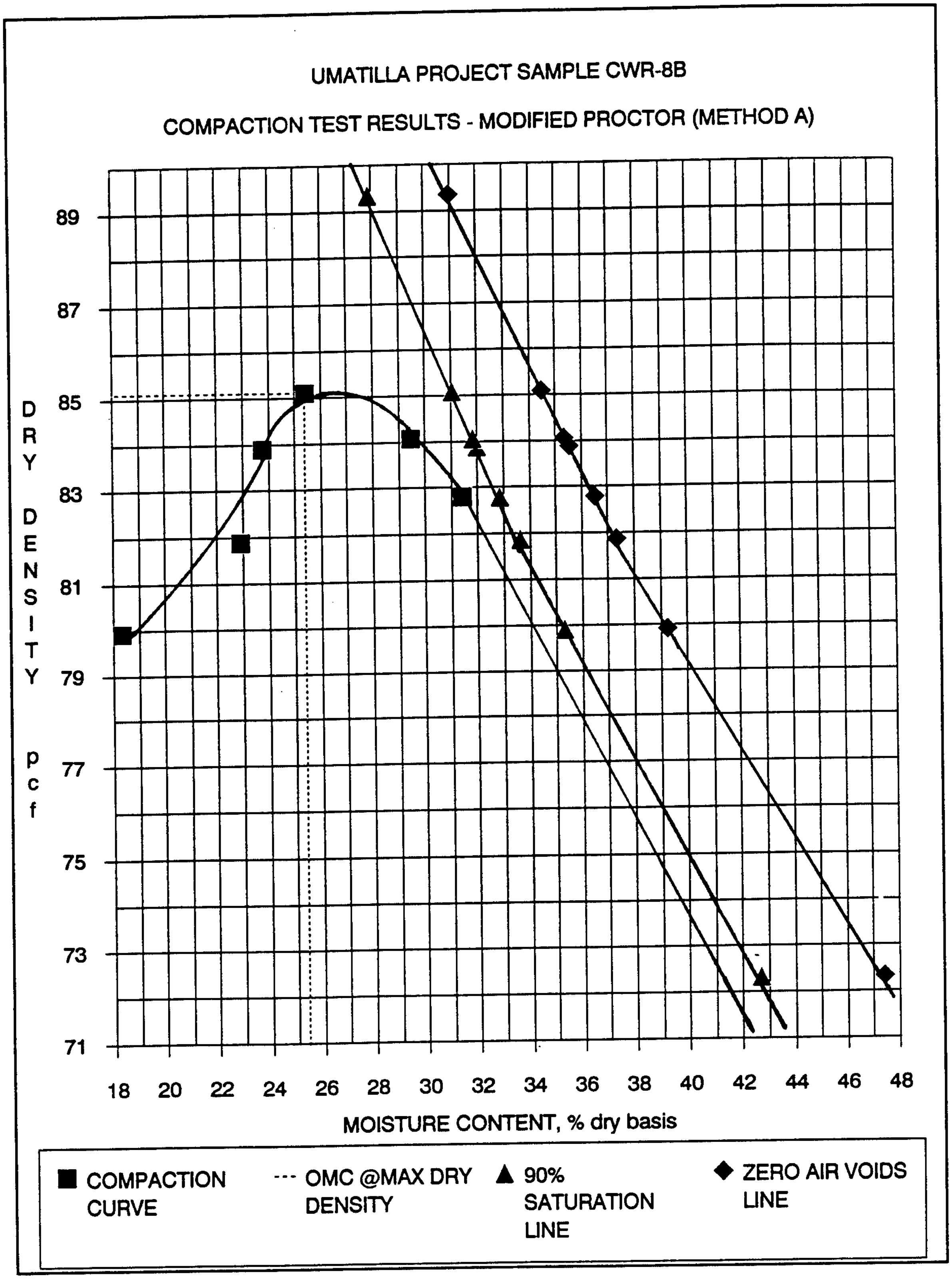
COMPACTION PARAMETERS							
Test Method	Mold Size			Compaction Method			
	Diameter inches	Height inches	Volume cc	Rammer Weight, lb	Rammer Drop, inch	# of Layers	# Blows per Layer
Modified proctor Method A minimum 4 points	3.984	4.570	933.7	10.0	18	5	25

COMPACTION TEST MEASURED RESULTS						
Dry Unit Weight, pcf	79.9	81.9	83.9	85.1	84.1	82.8
Moisture Content, %	18.3	22.9	23.7	25.4	29.5	31.4
Saturated Moisture Content, %	39.2	37.3	35.5	34.5	35.3	36.5
90% Saturated Moisture Content, %	35.3	33.6	32.0	31.0	31.8	32.8

COMPACTION CURVE ANALYSIS/RESULTS						
% of Maximum Dry Density	100	95	90	85		
Dry Density, pcf	85.1	80.8	76.6	72.3		
Moisture Content, %	25.4	33.2	37.5	41.2		
% Points Wet of Optimum	0.0	7.8	12.1	15.8		

NOTES

WESTON ENVIRONMENTAL TECHNOLOGY LABORATORY



APPENDIX C

DEFINITION OF TERMS

APPENDIX C

DEFINITION OF TERMS

V_{si}	=	Volume of solids in 1 ft^3 of finished compost
γ_{wet}	=	Bulk density of finished compost (lbs/ft^3)
G_s	=	Specific gravity of the compost solids
V_{wi}	=	Volume of water in 1 ft^3 of finished compost
V_{ai}	=	Volume of air in 1 ft^3 of finished compost
W_{si}	=	Weight of solids in 1 ft^3 of finished compost
V_F	=	Compacted volume of compost in backfill
V_{wf}	=	Volume of water in 1 ft^3 of backfilled compost